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Effect of cell wall properties of plant tissue on porosity and shrinkage of dried apple

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Abstract

In this study cell wall properties; moisture distribution, stiffness, thickness and cell dimension have been taken into consideration. Cell wall stiffness dependent on complex combination of plant cell microstructures, composition and water holding capacity of the cell. In this work, some preliminary steps taken by investing cell wall properties of apple in order to predict change of porosity and shrinkage during drying. Two different types of apple cell wall characteristic were investigated to correlate with porosity and shrinkage after convective drying. A scanning electron microscope (SEM), 2N Intron, a pyncometer and image J software were used in order to measure and analyze cell characteristics, water dynamics, porosity and shrinkage. Cell stiffness of red delicious apple was found higher than granny smith apples. A significant relationship has found between cell wall characteristics and both heat and mass transfer. Consequently, evolution of porosity and shrinkage noticeably influenced during convective drying by the nature of cell wall. This study has brought better understanding of porosity and shrinkage of dried food stuff in microscopic (cell) level and would provide better insight to attain energy effective drying process and quality food stuff.

Keywords: cell wall characteristics, compressive deformation, drying kinetics, porosity, microstructure

1.Introduction

Since the moisture content of fresh fruits and vegetables is more than 80%, they are classified as highly perishable commodities[1]. Food is one of the most complex materials in natural form and the fundamental understanding of food drying has not been fully established [2]. Lack of proper processing causes considerable damage and wastage of seasonal fruits in many countries, which is estimated to be 30–40% in developing countries [3]. Drying of foodstuffs is an important and the oldest method of food processing. Many physical and chemical changes occur in foods during the drying process. The quality of dehydrated product is affected by a number of factors and is dependent on the quality of raw material, method of preparing, processing treatments and drying conditions[4-6]. The first objective of drying is to remove water and hence to stabilize the food product. However, during food drying, many physic-chemical changes occur simultaneously resulting in a modified overall quality [7].Drying Kinetics and product quality significantly depends on food physical properties such as, structure , components, maturity; and drying conditions. In order to achieve better quality of dried food, optimum drying conditions is essential for particular food material properties.

Biological materials, especially plant tissue encompasses very complex nature due to its anisotropy, porous, hygroscope attributes. Therefore, most of the time it is quite difficult to get reproductive sample for plant tissue in order investigates. In addition, the results generally precisely match only with the precisely defined conditions.

Fresh apple has a large amount of intercellular space which contains air spaces volume, 22- 38% of total tissue volume [8]. In other words, frees apple flesh are intensely porous with initial porosity 0.22-0.38. Amongst the apples, granny smith contains higher initial porosity with 0.33, due to larger cell dimension and thinner cell wall thickness. Larger cells in plant tissue generally are found loosely packed than smaller cell. Although getting almost same amount moisture content (86.9% and 87.5% for granny smith and red delicious respectively) and density (789 kg/m^3 and 766 kg/m^3 for granny smith and red delicious respectively), two different apple shows different drying rate. Moreover, many studies confirmed the role of mechanical properties of plant- based food on flavors release, bio-availability of nutrients and textural perception [9]. However, researchers have not dealt with the mechanical properties of cell wall in order to get the relationships of it with drying kinetics and physicochemical characteristics of dried food such as porosity, microstructure and shrinkage. In these study two types of apple namely granny smith and red delicious were subjected to investigate the characteristics of cell wall. In this work, an attempt was carried to investigate the cell wall characteristics in terms of cell wall thickness, stiffness, cell diameter, water distribution within cell wall on drying rate and dried food physical properties.

2. Material and Method

Two types of apple namely granny smith and red delicious apple purchased from supermarket .Firstly apples were sliced in the dimension of 10X16X16 mm to analysis the compression test as shown in the Figure 1. Then 3.5mm thick apple samples were kept in convective dryer with 70 ^{0}C for 180 minutes.

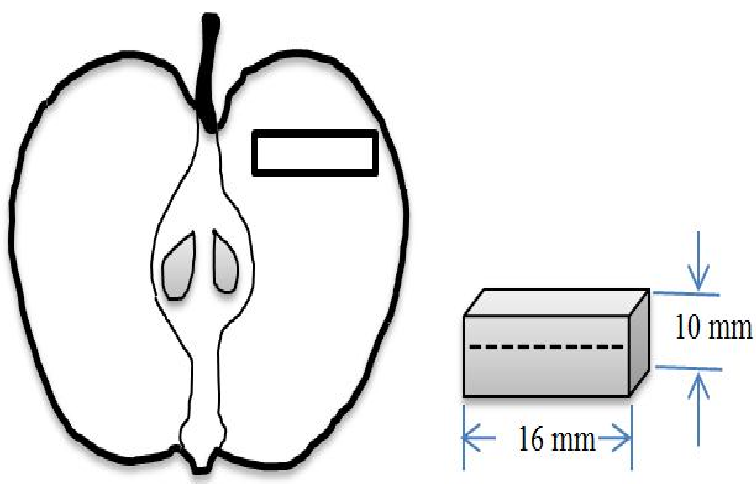


Figure 1: Sample prepare for mechanical properties (compression test)

A Quanta 200 Scanning Electron Microscope (SEM) was used in order to analyze the microstructure of both fresh and dried apple slice. For getting the compression properties, in this study, 2kN Intron 5569 was deployed. A strain rate of 1mm/min was applied to get 3.5 mm compressive extension. Meanwhile, a pycnometer of the model Pentapyc 52000e was used to get the porosity of fresh and dried samples of apple. Apart from these, ImageJ 1.47v software was used to analysis the microstructure to achieve cell wall thickness before and after drying, and cell dimension.

3. Result and Discussion

Cell Stiffness and Drying Rate

The result as shown in figure that red delicious apple tissue get more stiffness than granny smith apple due to the value of Young's modulus of elasticity of the former one is higher that the later one. This result , as shown in Figure 2, represents that to get same amount of compressive deformation granny smith requires less energy than red delicious apple.

There is a significant similarity between compressive test and drying process. The result, as shown in Figure 3, indicate that moisture migration rate is higher for granny smith than red delicious. This result confirms that in order to remove same amount of water red delicious apple takes more heat energy than granny smith.

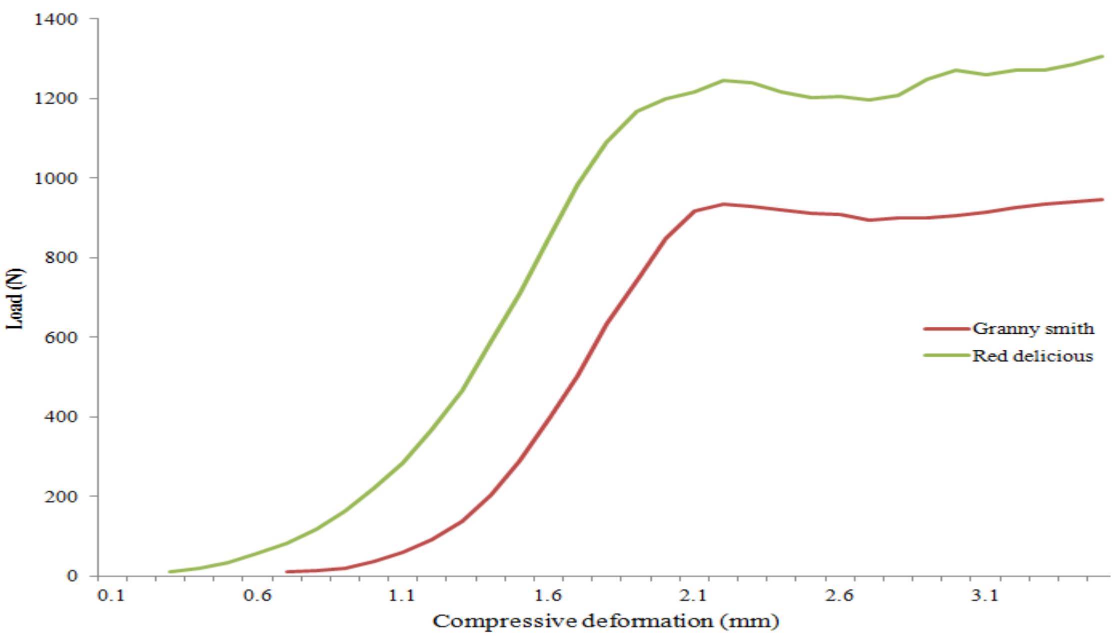


Figure 2: Compressive extension characteristics of apples

Not only is the Young modulus of elasticity Poisson's ration different for these two types of apple. From the literature , it was found that the value of Poisson's ratio is 0.169-0.244 [10] for granny smith and 0.155-0.207 [11]. Therefore, there is a positive was found that the relationship of water migration by mechanical and heat energy demonstrate similar trend. Interestingly, this correlation is related cell wall characteristics facilitates or hinders the water migration in both the cases of mechanical and thermal energy application.

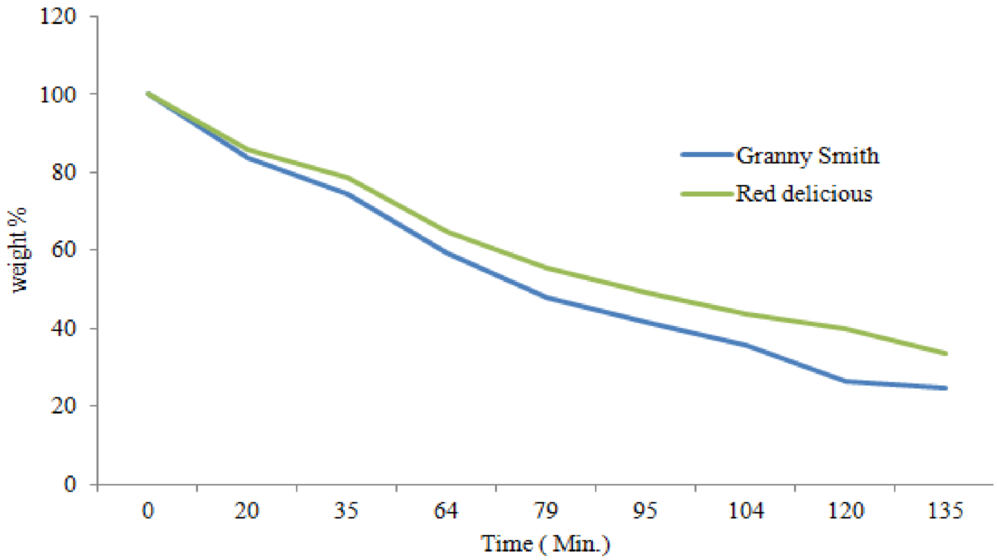


Figure 3: Weight loss of apple slice in convective drying at 70^0 C

Cell Dimension and Porosity

Cell dimension influence the rigidity of cell wall and tissue of plant materials. Higher cell dimension causes loose packing of cells, consequently density, rigidity, intercellular spaces are affected significantly. Figure 4 compares the microstructures of fresh and dried granny smith and red delicious apples. The results obtained from microstructure analysis of samples provide granny smith encompasses larger cells than red delicious, as shown in Figure 5. This consistence with the

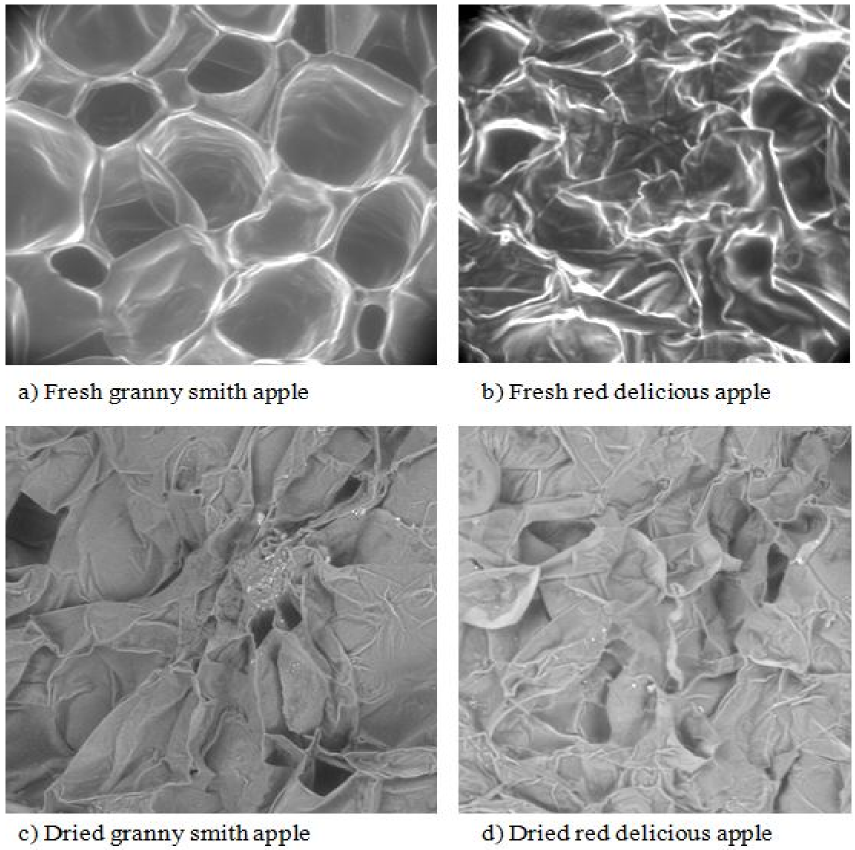


Figure 4: Microstructure of fresh and dried apple samples (500x)

Previous literature which provides high initial porosity of granny smith is 0.33 [8]. It was also found from the pycnometer data; dried granny smith apple comprises higher porosity due to larder cell dimension and loose packing of cells.

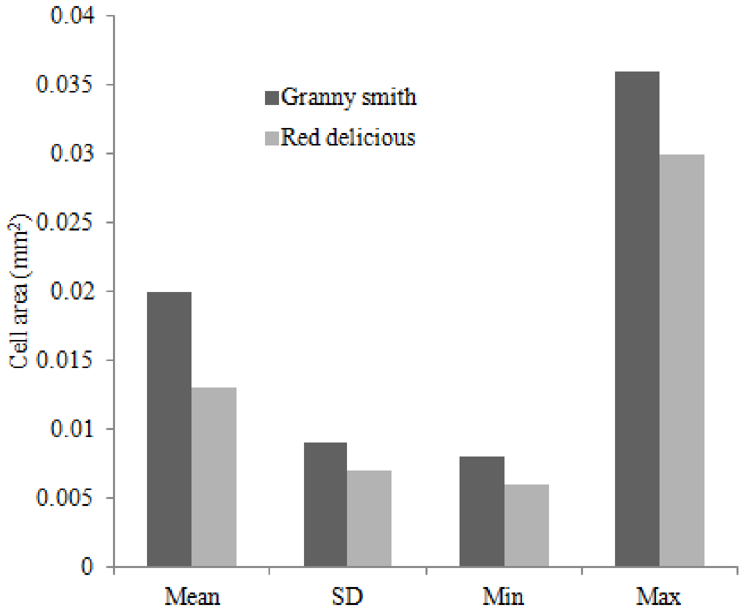
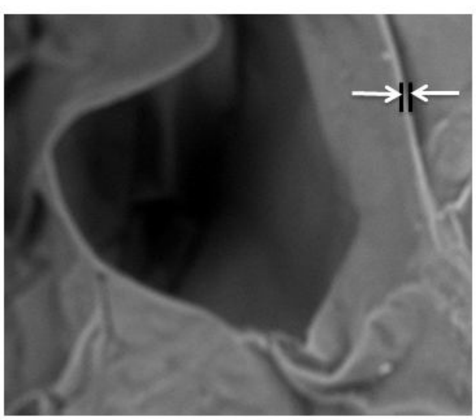


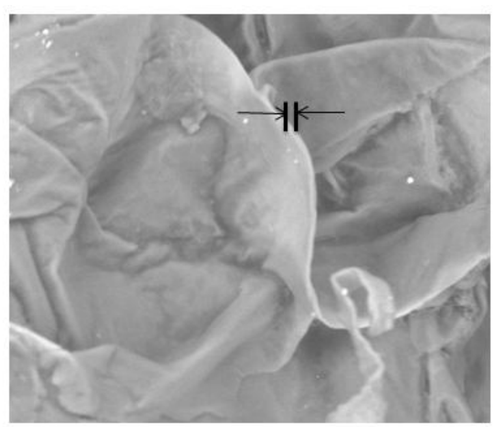
Figure 5: Cell dimension of two types of apple

Cell Wall Thickness and Water Distribution

Besides the cell dimension, water content in cell wall influence both cell wall thickness and water distribution within cell wall and tissue as well. Cell wall thickness analysis, as shown in Table 1, provides red delicious with thicker cell wall than granny smith (average cell wall thickness for 9.312 µm and 11.405 µm for granny smith and red delicious respectively) as fresh state. On the other hand, after drying the cell wall shrinks more in red delicious, as shown in Figure 6, with average 78.68% whereas cell wall of granny smith shrinks almost 50% of fresh thickness. This result indicates more bound water in red delicious within the cell wall.



a) Granny smith apple



b) Red delicious apple

Figure 6: Cell wall thickness of dried apple (1220x)

These findings of cell wall characteristics might be the explanation of why red delicious apple takes more energy to compress and drying to certain moisture removal. This property of cell wall also can interoperate why

Table 1: Cell wall thickness of fresh and dried apple

	Granny smith apple			Red delicious apple		
	Fresh (μm)	Dried (μm)	Cell wall shrinkage (%)	Fresh (μm)	Dried (μm)	Cell wall shrinkage (%)
Average (μm)	9.312	4.685	49.69	11.405	2.432	78.68
Minimum (μm)	6.734	3.769	44.03	7.678	1.65	78.51
Maximum (μm)	11.785	6.281	46.70	14.458	3.527	75.61

the cell wall collapse more in red delicious apple than the granny smith apple. So, the most striking result to emerge from the data is that porosity of dried food significantly depends on the nature of cell wall. Further investigation is required to get more insight of the cell wall properties in order to achieve optimum drying conditions and better quality of dried food.

4. Conclusion

Drying kinetics and dried food quality are subject to drying conditions and fresh food properties. In this study, cell wall characteristics in terms of stiffness, wall thickness, moisture distribution, and cell dimension. Drying kinetics and compressive deformation were found in similar trend for the apple slices. Therefore, drying kinetics noticeably depends on cell wall characteristics. Moreover, dried food quality, especially physical attributes such as porosity, shrinkage and microstructure are significantly affected by the cell wall characteristics. The findings of this study would bring new understanding of relationship of mechanical properties of plant tissue with drying kinetics and dried food quality.

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